Investigation of phytoplankton flora of a temple tank in cosmopolitan Chennai city, India

Desingurajan P, Manikandan S, Elayasurya R and Sankaran B*

Department of Plant Biology and Plant Biotechnology, Presidency College, Chennai, India

Abstract

Phytoplankton flora of Kaaraneeswarar temple tank, Saidapet was studied. It is situated in the heart of the Cosmopolitan Chennai City. The present study aimed to identify the Chlorophytes inhabiting the tank. Generally green algae dominate the freshwater ecosystem. The taxa identified comprised of 38 species belonging to 23 genera. Sphearopleales had 24 species, followed by Chlorellales with ten species. Trebouxiophyceae ordo incertae sedis was represented by two species. One species of Chlamydomonadales and Charophyte were identified.

Keywords: *Lacunastrum, raphidocelis, heynigia, hindakia, microalgae, phycology.*

INTRODUCTION

Microalgal diversity study plays a very critical role in today's world. India being a tropical nation is blessed with species richness. The subtropical nature and geographic position as made it a haven for biological species. Continuous microalgal diversity study in tropical regions has led to discovery of several new species (Neustupa et al., 2007; Rindi & Lopez-Bautista, 2007; Elias et al., 2008; Zhang et al., 2008; Neustupa et al., 2009). The study microalgal biodiversity is gaining importance for its ecological benefits and biotechnological potential. The phytoplankton community contributes most of the organic carbon available to pelagic food chains (Reynolds, 2006). They are very important taxa in the world as they provide solutions for major world complications. Microalgae are studied for its lipid content to be used as biofuel, an alternative to fossil fuels. Microalgae provide solutions for many manmade disasters. Phycoremediation can fix the long term environment damage caused due to human intervention.

Algal research to cater the energy needs of human development is at the fore. They are probable source of bioenergy, medicinal products, biofertilizer, food and fodder (Mobin et al., 2002). Microalgae possess natural compounds which are used as useful components (Gouveia et al., 2010). They are source of high value biochemical like astaxanthin, β-carotene, etc (Leon et al., 2003). Microalgae are source for many compounds which have a significant role in our daily lives (Sweetman, 2009). Microalgae are going to be the super food in near future with high nutrient content. In fact it has created a new avenue in the form of nutraceuticals for entrepreneurs.

Phycology was in limelight for a very long time in Tamil Nadu and it was blessed with stalwarts recognized worldwide. At present the study of phycology is dwindling in Tamil Nadu. The times and methods have changed. In recent times, modern techniques are more sought out method for identifying the species with precision. The quantity and quality of water has changed a lot which play a big role in the abundance of microalgae. Microbial ecosystems are now defined due to human influences (Omar, 2010). Irrespective of their nature, any water body will harbour microalgae in it Figure 1.

In India, ponds are always associated with temples. At present, about 2359 temple tanks are there in Tamilnadu State of India (downtoearth.org). In Chennai, there are plenty of temples with an adjacent pond. The pond has a significant role both spiritually and socially. Water from the pond is used for all temple activities. It will recharge the groundwater of the area (Sankaran & Thiruneelagandan, 2015). Generally they dry during summer and it gets back water again during the monsoon months. In South India, temple tanks along with sacred trees and sacred groves have been vital for environment conservation (Amirthalingam & Muthukrishnan, 2004). Karaneeswarar temple has Lord Shiva as its deity and it is located amidst the urban sprawl in Saidapet, Chennai, India. The pond (Photo 1) is in existence for nearly 400 years. The geographic coordinates is 18° 1' 29" North and 80° 13' 21" East (Map 1) and it spreads over

(A) (B)

Figure 1: (A) Karaneeswarar Temple Pond, (B) Map.

an area of 40000 square feet and it is 35 feet deep. The Hindu religious and cultural endowments, Government of Tamil Nadu maintain the temple and the pond.

The green colour of the pond (sampling area) showed that it has very high species richness. The Chlorophyta taxa are the largest and diverse among the various micro algal groups (Perez *et al*., 2002). The present study has showed dominance in Chlorophyte members. 37 species were represented by Chlorophyte and One species from Charophyte. Among the members of Sphaeropleales (Class Chlorophyceae), Scenedesmaceae was the maximum with twelve species, followed by eight species from Hydrodictyaceae and minimum was Selenastraceae with four species. Tetrasporaceae of Chlamydomonadales had only one species. Chlorellales (Class Trebouxiophyceae) was represented by ten species with eight species of Chlorellaceae and two species of Oocystaceae. Trebouxiophyceae ordo incertae sedis (Class Chlorophyceae) was the minimum with only two species.

MATERIALS AND METHODS

The water sample was collected in January 2021. It was taken from different spots. The sample was fixed with formalin and brought to the laboratory for microscopic examination. Microphotographs of microalgae were taken using Microvision, Digital Camera (5.1 MP, 1/25" APTINA CMOS SENSOR). The identification was carried out using books, monographs and web resources. The standard books and monographs Prescott (1962); Philipose (1967); Das & Adhikary (2014); Algaebase (Guiry, 2021), an online resource for listing the World's Algae was used for species confirmation and its recent name.

RESULTS AND DISCUSSION

Empire – Eukaryota Chatton, 1925.

Kingdom – Plantae Haeckel, 1866.

Subkingdom – Viridiplantae Cavalier-Smith, 1981.

Infrakingdom- Chlorophyta infrakingdom Cavalier-Smith, 1993.

Phylum – Chlorophyta Reichenbach, 1834.

Subphylum – Chlorophytina Cavalier-Smith, 1998.

Class – Chlorophyceae Wille in Warming, 1884.

Order – Sphaeropleales Luerssen, 1877.

Family – Hydrodictyaceae Dumortier 1829

Lacunastrum gracillimum (West & G. S. West) H. McManus (Figure 1)

Basionym: *Pediastrum duplex* var. *gracillimum* West & G. S. West

Colony with 16 cells; Intercellular spaces are larger in colonies; Colony is 60 μm in diameter; Cells are narrow; Outer or marginal cells has two long processes and inner cells have shorter processes; Cells are 18 μm in diameter.

Monactinus simplex (Meyen) Corda (Figure 2)

Basionym: *Pediastrum simplex* Meyen

Colony with 8 cells and 65 μm in diameter; Outer cells possess two tapering processes; Inner cells are H shaped; Intercellular spaces are present; Cells are 12 μm long.

Parapediastrum biradiatum (Meyen) E. Hegewald (Figure 3)

Basionym: *Pediastrum biradiatum* Meyen

Colony with 16 cells and 51 μm in diameter; Outer cells have two V shaped lobes; Outer most cells are attached at the base with deep incision; H shaped inner cells; Cells are 12 μm in diameter.

Pediastrum duplex Meyen (Figure 4)

Colony is eight celled, 75 – 80 μm in diameter; Cells are H shaped and shows parallel arrangement with the other cells; Intercellular spaces is present; Cells are 18 μm in diameter.

Stauridium tetras (Ehrenberg) E. Hegewald (Figure 5)

Basionym: *Micrasterias tetras Ehrenberg*

Colonies are circular or square shaped without intercellular spaces; Colonies have 4 to 8 cells and reach up to 25 – 30 μm in diameter; Cells are divided by a deep incision and with triangular processes extending outward; Cells are 7 to 8 μm in diameter.

Tetraedron minimum (A. Braun) Hansgirg (Figure 6)

Basionym: *Polyedrium minimum* A. Braun

Quadrangular cells with concave sides; Flat cell body; Cell corners possess small papillae; Cells are small and 9 µm in diameter.

Tetraedron triangulare Korshikov (Figure 7)

Triangular cells with concave lateral sides; Flat cell body; Cell angles are rounded; Cells are 30 µm in diameter.

Tetraedron trilobulatum (Reinsch) Hansgirg (Figure 8)

Basionym: *Polyedrium trilobulatum* Reinsch

Triangular cells with sides deeply concave; Cell angles are rounded; Cell corners possess small papillae; Cells are 33 µm in diameter.

Family – Scenedesmaceae Oltmanns, 1904.

Subfamily – Desmodesmoideae

Desmodesmus armatus (Chodat) E. Hegewald 2000. (Figure 9)

Basionym: *Scenedesmus hystrix* var *armatus* Chodat

Colonies of 2, 4 (8) celled; Ellipsoidal cells with cone like rounded ends; Outer cell has polar spines; Inner cells are devoid of spines. Length of the cells is 11 µm and width is 3 µm; Spines are 11 µm.

Desmodesmus armatus var. *bicaudatus* (Guglielmetti) E. Hegewald 2000. (Figure 10)

Basionym: *Scenedesmus acutiformis* var. *bicaudatus Guglielmetti*

Colonies of four; Cells are ellipsoidal; Outer cells have spine at poles arranged in opposite sides; Inner cells without spines; Length of the cells is 13 µm long and width is 6 µm; Spines are 12 µm.

Desmodesmus bicaudatus (Dedusenko) P. M. Tsarenko (Figure 11)

Basionym: *Scenedesmus bicaudatus* Dedusenko

Colonies of two; Oblong cells with rounded ends; Outer cells have spine at poles arranged in opposite sides; Length of the cells is 11 µm long and width is 6 µm; Spines are 17 µm.

Desmodesmus brasiliensis (Bohlin) E. Hegewald (Figure 12)

Basionym: *Scenedesmus brasiliensis* Bohlin

Colonies are flat with four cells; Elliptical to oblong cells; One to two polar denticles seen in inner cells; Length of the cells is 19 µm long and width is 6 µm; Spines are very small.

Desmodesmus communis (E. Hegewald) E. Hegewald (Figure 13)

Basionym: *Scenedesmus communis* E.Hegewald

Dense elongated with cone like rounded cells in colonies of four; Spines are present at the apex of terminal cells; Cell wall is smooth; Length of the cells is 18 µm long and width is 6 µm; Spines are 15 µm.

Desmodesmus insignis (West & G. S. West) E. Hegewald (Figure 14)

Basionym: *Scenedesmus quadricauda* var. *insignis* West & G.S.West

Colonies of four cells; Elliptical cells with rounded ends; Outer cells are shorter than the inner cells; Length of the cells is 9 µm long and width is 3 µm; Spines are very long and reach up to a length of 18 µm.

Desmodesmus protuberans (F. E. Fritsch & M. F. Rich) E. Hegewald (Figure 15)

Basionym: *Scenedesmus protuberans* F.E.Fritsch & M.F.Rich

Colonies of four; Cylindrical cells with rounded ends; Inner cells are longer; Outer Cells possess long spines at their poles; Length of the cells is 13 µm long and width is 3 µm; Spines reach up to a length of 13 µm.

Scenedesmus obtusus Meyen (Figure 16)

Colonies of four; Ovate cells with papilla at their polar ends; Cells are seen in zigzag arrangement; Each cell is in contact with the adjacent cell up to half their length; Spines absent; Length of the cells is 14 µm long and width is 7 µm.

Scenedesmus tibiscensis Uherkovich (Figure 17)

Colonies of eight; Ovate cylindrical cells with rounded ends; Cells are arranged alternately; Spines are absent; Length of the cells is 16 µm long and width is 6 µm.

Tetradesmus bernardii (G. M. Smith) M. J. Wynne (Figure 18)

Basionym: *Scenedesmus bernardii G.M.Smith*

Colonies of four; Crescent shaped outer and fusiform inner cells with acute ends; Outer cells median portion attached to the ends of the inner cells; Inner cells are attached in the middle; Spines absent; Cells are 15 µm long and 4 µm wide.

Subfamily – Scenedesmoideae

Tetradesmus lagerheimii M. J. Wynne & Guiry (Figure 19)

Colonies of four; Elongated fusiform inner and crescent shaped outer cells with acute ends; Cells are 12 µm long and 3 µm wide.

Westella botryoides (West) De Wildeman (Figure 20)

Basionym: *Tetracoccus botryoides* West

Colonies with 16 cells; Spherical cells arranged in fours or eights; Cells are linked wall fragments of the parental cell wall; Colony is not enveloped by mucilage; Cells are 9 µm in diameter.

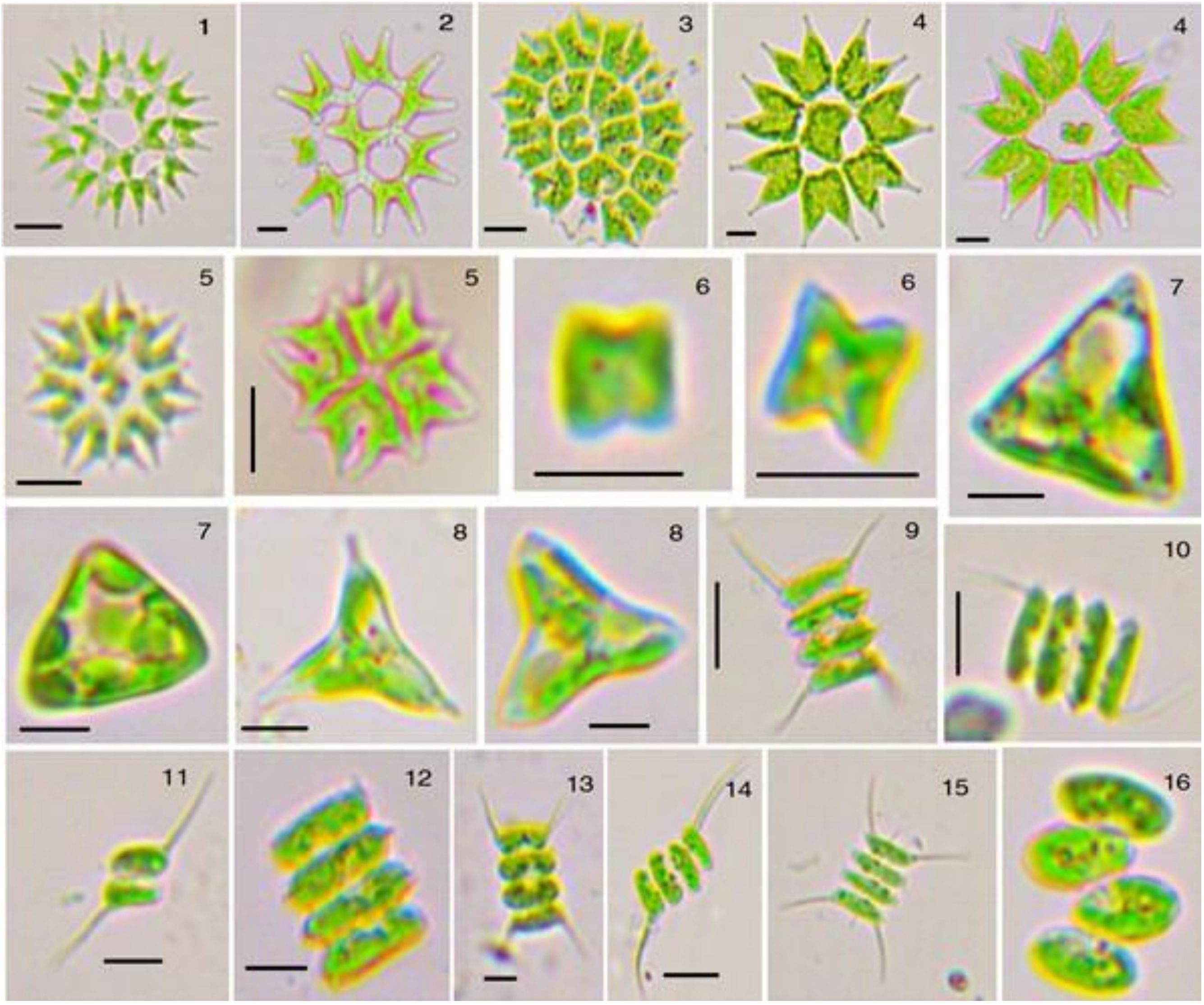

Figure (Plate 1) : 1. *Lacunastrum gracillimum* 2. *Monactinus simplex* 3. *Parapediastrum biradiatum* 4. *Pediastrum duplex* 5. *Stauridium tetras* 6. *Tetraëdron minimum* 7. *Tetraëdron triangulare* 8. *Tetraëdron trilobulatum* 9. *Desmodesmus armatus* 10. *Desmodesmus armatus* var. *bicaudatus* 11. *Desmodesmus bicaudatus* 12. *Desmodesmus brasiliensis* 13. *Desmodesmus communis* 14. *Desmodesmus insignis* 15. *Desmodesmus protuberans* 16. *Scenedesmus obtusus*

Family – Selenastraceae Blackman and Tansley 1903

Kirchneriella lunaris **(Kirchner) Mobius (Figure 21)**

Crescent shaped cells; Cells termini are rounded; Cells are 9 *µm* long and 4 *µm* wide.

Monoraphidium contortum **(Thuret) Komárková-Legnerová (Figure 22)**

Basionym: *Ankistrodesmus contortus* Thuret

Elongated fusiform cells tapering to pointed ends; Crescent shaped cells; Cells are 15 *µm* long and 3 *µm* wide.

Monoraphidium komarkovae **Nygaard (Figure 23)**

Needle shaped cells tapering to pointed ends; Cells are 35 – 40 *µm* long and 4 – 5 *µm* wide.

Raphidocelis danubiana **(Hindák) Marvan, Komárek & Comas (Figure 24)**

Basionym: *Kirchneriella danubiana* Hindák

Colony with four cells; Horse shoe shaped cells; Cells are irregularly arranged; Poles are rounded; Cells are 12 µm long and 2 µm wide.

Order – Chlamydomonadales F. E. Fritsch 1927

Family – Tetrasporaceae Wittrock 1872

Tetraspora gelatinosa **(Vaucher) Desvaux (Figure 25)**

Colony is non-motile with four cells; Colony is present in homogenous mucilage; Cells are spherical; Cells are 14 *µm* in diameter.

Class – Trebouxiophyceae Friedl 1995

Order – Chlorellales Bold & M. J. Wynne 1978

Family – Chlorellaceae Brunnthaler 1913

***Acanthosphaera zachariasi* Lemmermann (Figure 26)**

Spherical cell body with elongated spines around; Basal portion of the spine is thickened, narrowing to a fine bristle; Cell is 23 µm in diameter; Spines 15 µm in length.

***Dictyosphaerium ehrenbergianum* Nägeli (Figure 27)**

Oval to ellipsoidal cells; Mucilage filaments are dichotomously branched connecting radially by their longer side of the cells; Cells are 6 µm long and 4 µm wide.

***Dictyosphaerium reniforme* Bulnheim (Figure 28)**

Reniformcells; Mucilage filaments are di ortetrachotomously branched connecting radially by their convex side of the cells; Cells are 11 µm long and 5 µm wide.

***Heynigia dictyosphaerioides* C. Bock, Proschold & Krienitz (Figure 29)**

Spherical cells; Mucilage filaments are di ortetrachotomously branched connected to the base of the cell; Cells are 5 – 6 µm in diameter.

***Heynigia riparia* C. Bock, Proschold & Krienitz (Figure 30)**

Spherical cells; Mucilage filaments are di ortetrachotomously branched connected to the base of the cell; Cell arrangement is Cells are 6 – 7 µm in diameter.

***Hindakia fallax* (Komárek) C. Bock, Proschold & Krienitz (Figure 31)**

Basionym: *Dictyosphaerium tetrachotomum* var. *fallax* Komárek

Oval to spherical cells; Cells are slightly asymmetric and tapering to a more or less sharp point; filaments are fine and branched pseudotetrachotomously; Cells are 6 µm long and 3 µm wide.

***Hindakia tetrachotoma* (Printz) C. Bock, Pröschold & Krienitz (Figure 32)**

Basionym: *Dictyosphaerium tetrachotomum* Printz

Colony with 16 cells; Oval to elliptical cells; Mucilage filament is regular and connecting with the ends of the cells; Cells are 8 µm long and 5 µm wide.

***Micractinium pusillum* Fresenius (Figure 33)**

Colony with 4 cells; Spherical cells with hyaline spines; Cells are 8 *µm* in diameter.

Family – Oocystaceae Bohlin 1901

Subfamily – Makinoelloideae

***Willea apiculata* (Lemmermann) D. M. John, M. J. Wynne & P. M. Tsarenko (Figure 34)**

Basionym: *Staurogenia apiculata* Lemmermann

Pie shaped Cells; Cells joined in groups of four; Cells are seen within flattened colonies; Colony has a crucified central part; Cells are 8 *µm* long.

***Willea irregularis* (Wille) Schmidle (Figure 35)**

Basionym: *Crucigenia irregularis* Wille

Irregular reniform cells; Cells joined in groups of four; Cells are seen within flattened colonies; Cells are arranged irregularly; Cells are 11 *µm* long.

Order – Trebouxiophyceae ordo incertae sedis

Family – Trebouxiophyceae incertae sedis

***Crucigenia fenestrata* (Schmidle) Schmidle (Figure 36)**

Basionym: *Staurogenia fenestrata* Schmidle

Coenobium is rhomboidal with a large internal space; Trapezoid cells; Cells outer side is straight or slightly curved; Cells are 12 *µm* long and 15 *µm* wide.

Basionym: *Staurogenia* tetrapedia Kirchner

Triangular cells; Cells are joined in groups of four; Cells are seen in flattened colonies; Cells are 5 *µm* long.

Infrakingdom – Streptophyta infrakingdom Cavalier Smith

Phylum – Charophyta Migula

Class – Zygnematophyceae Round Ex Guiry

Subclass- Zygnematophycidae Melkonian, Gontcharov & Marin 2019

Order – Desmidiales Bessey 1907

Family – Desmidiaceae Ralfs 1848

***Euastrum amoenum* F. Gay (Figure. 38)**

Solitary cells with narrow apical incision; Semi cells are rectangular in shape; Cells are deeply constricted in the mid region; Cell is 32 *µm* long.

The Chlorophyte taxa are identified for a quite a long time, information on their taxonomy and phylogeny is still lacking (Zou et al., 2016). Morphological features like cell shape, chloroplast site, reproduction, colony construction, flagella type, etc are used to identify microalgae (Leliaert et al., 2012). Identification of common genera of freshwater bodies like Desmodesmus and Scenedesmus species

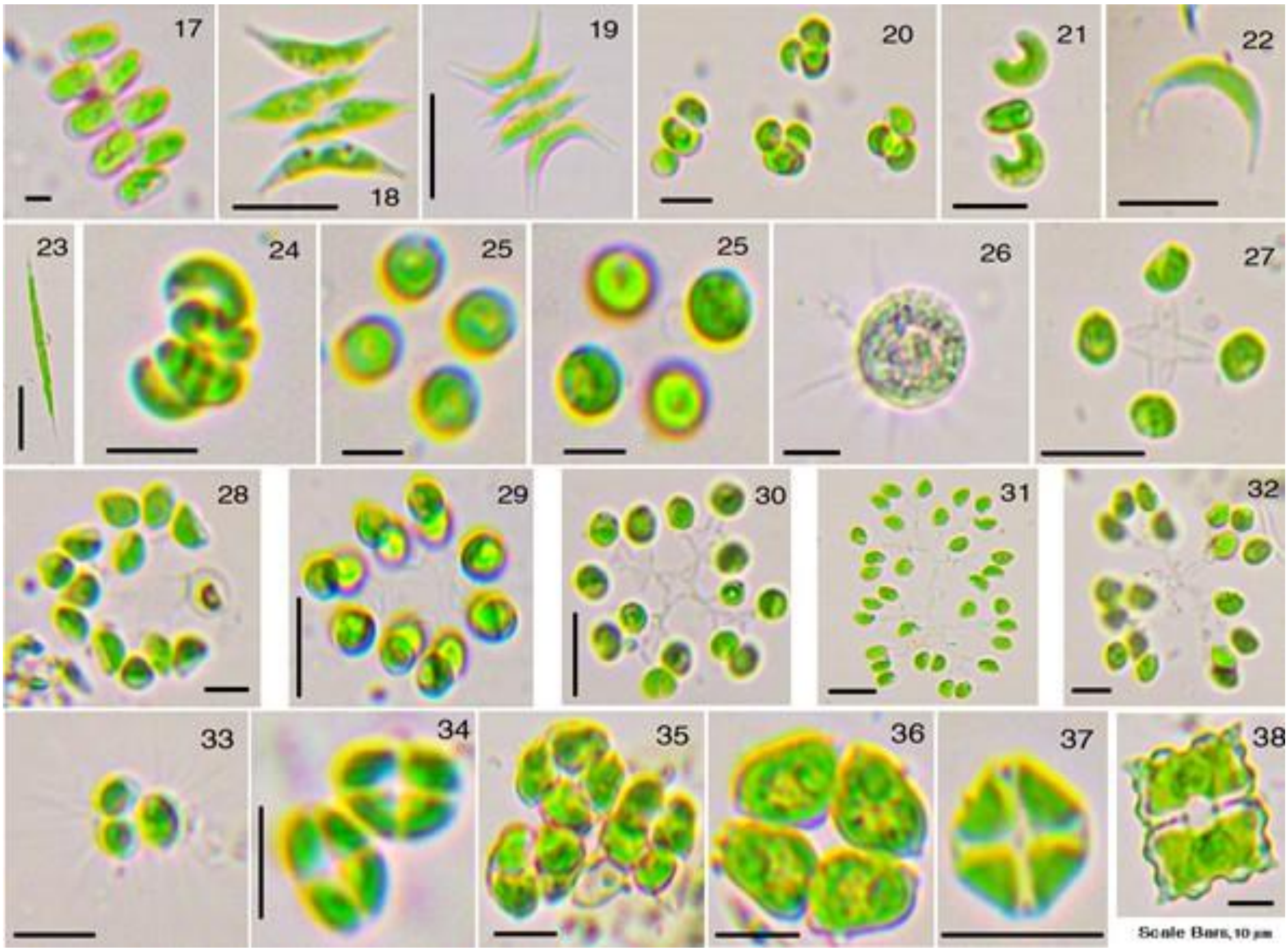

Figure (Plate 2) : 17. *Scenedesmus tibiscensis* 18. *Tetradesmus bernardii* 19. *Tetradesmus lagerheimii* 20. *Westella botryoides* 21. *Kirchneriella lunaris* 22. *Monoraphidium contortum* 23. *Monoraphidium komarkovae* 24. *Raphidocelis danubiana* 25. *Tetraspora gelatinosa* 26. *Acanthosphaera zachariasi* 27. *Dictyosphaerium ehrenbergianum* 28. *Dictyosphaerium reniforme* 29. *Heynigia dictyosphaerioides* 30. *Heynigia riparia* 31. *Hindakia fallax* 32. *Hindakia tetrachotoma* 33. *Micractinium pusillum* 34. *Willea apiculata* 35. *Willea irregularis* 36. *Crucigenia fenestrata* 37. *Lemmermannia tetrapedia* 38. *Euastrum amoenum*

becomes very difficult due to small variations among the identified species (Johnson et al., 2007). The phenotype of Scenedesmus is affected by nutrient availability, light quality, predators present in the freshwater environment (Trainor, 1992).

Hindakia and Heynigia are two new genera established based on their phylogenetic relationship with Dictyosphaerium ehrenbergianum (Bock et al., 2010). Based on morphological variations and Phylogenetics two species of these two genera were established. Heynigia dictyosphaerioides, Heynigia riparia, Hindakia fallax and Hindakia tetrachotoma, Acanthosphaera zachariasi are reported for the first time in India.

Scenedesmus is economically important taxa with high biotechnological potential. It is used in biodiesel production (Wu et al., 2013). Heavy metal contamination in water can be reduced using Scenedesmus (Terry & Stone, 2006). With very high antioxidant content it has the ability to reduce cancer risk (Jhony et al., 2017). Many species of Scenedesmus are used as single cell protein.

CONCLUSION

The present research revealed presence of more species from the taxa chlorophyta. A single sample collection study has shown the presence 38 taxa of chlorophytes. The number of taxa identified in the sample was 38. Chlorophyte was dominating with 37 species. One species was represented by a desmid (Charophyte). Sphaeropleales was the order with maximum number of 24 species. The order Chlorellales had ten species. Order Trebouxiophyceae ordo incertae sedis had two species. One species was documented from Chlamydomonadales and Desmidiales. *Desmodesmus* was the genera with maximum of seven species. *Tetraedron* followed with three species. Two species each were seen in *Scenedesmus*, *Tetradesmus*, *Monoraphidium*, *Dictyosphaerium*, *Heynigia*, *Hindakia*, *Willea*. Fourteen genera represented with one species each.

In depth study of the pond will result in identification of more number of microalgae. It will add more number of species to the biodiversity registry. The pond can be a source for many economically important species.

ACKNOWLEDGEMENT

The authors would like to thank the authorities for helping in water sample collection from the temple tank. We would like to thank Maxar technologies for the satellite image of the temple tank. We would like to thank online resource the algaebase for aiding in identification and finding basionyms of the identified species.

REFERENCES

1. Amirthalingam M, Muthukrishnan N(2004). Temple Tanks of Chennai, C.P.R. Environmental Education Centre, Chennai.
2. Bock C, Proschold T, Krienitz L(2010). Two new *Dictyosphaerium*-morphotype lineages of the Chlorellaceae (Trebouxiophyceae): *Heynigia* gen. nov. and *Hindakia* gen. nov. Euro J Phyco 45(3): 267-277.
3. Das SK, Adhikary SP(2014). Freshwater algae of Eastern India. Daya Publishing House, New Delhi.
4. Elias M, Neustupa J, Škaloud P(2008). *Elliptochloris bilobata* var. *corticola* var. nov. (Trebouxiophyceae, Chlorophyta), a novel subaerial coccal green alga. Biologia 63, 791-798.
5. Johnson JL, Fawley MW, Fawley KP(2007). The diversity of *Scenedesmus* and *Desmodesmus* (Chlorophyceae) in Itasca State Park, Minnesota, USA. Phycologia, 46:2, 214-229.
6. Gouveia L, Marques A, Sousa J, Moura P, Bandarra N(2011). Food Science and Technology Bulletin, 7, 21-37.
7. Guiry MD, Guiry GM(2021). **AlgaeBase**. World-wide electronic publication, National University of Ireland, Galway. https://www.algaebase.org
8. Jhony HGZ, Augusto S, German D, Alexander G, Tatiana M, Vargas JF, Mariana P(2017). Automatic identification of *Scenedesmus* polymorphic microalgae from microscopic images. Pattern Analysis and Applications 21(2): 601-612.
9. Leliaert F, Smith DR, Moreau H, Herron MD, Verbruggen H, Delwiche CF(2012). Phylogeny and molecular evolution of the Green Algae. Crit. Rev. Plant. Sci. 31:1-46.
10. Mobin S, Chowdhury H, Alam F(2002). Commercially important bioproducts from microalgae and their current applications – a review. *Energy Procedia.* 60, 752-760.
11. Neustupa, J., Eliáš, M, Šejnohová, L(2007). A taxonomic study of two Stichococcus species (Trebouxiophyceae, Chlorophyta) with a starch enveloped pyrenoid. Nova Hedwigia, 84, 51-63.
12. Neustupa, J., Němcová, Y., Eliáš, M. and Škaloud, P(2009). Kalinella bambusicola gen. et sp. nov. (Trebouxiophyceae, Chlorophyta), a novel coccoid Chlorella-like subaerial alga from Southeast Asia. Phycological Research, 57: 159-169.
13. Omar WMW(2010). Perspectives on the use of algae as biological indicators for monitoring and protecting aquatic environments, with special reference to Malaysian freshwater ecosystems. *Trop. Life Sci. Res.*, 21, 51-67.
14. Perez MC, Comas A, Del Rio JG, Sierra JP(2002). Planktonic Chlorophyceae from the lower Ebro River (Spain). Acta Botanica Croatica. 61(2): 99-124.
15. Philipose MT(1967). Chlorococcales. I.C.A.R. New Delhi.
16. Prescott GW(1962). Algae of the western great lakes area. Dubuque. Iowa, W.C. Brown Co.
17. Reynolds, CS(2009). Ecology of phytoplankton. Cambridge, Cambridge University Press.
18. Rindi F, Lopez-Bautista JM(2008). Diversity and ecology of Trentepohliales (Ulvophyceae, Chlorophyta) in French Guiana. Cryptogamie, Algologie 29 (1): 13-43.
19. Sankaran B, Thiruneelagandan E (2015). Microalgal diversity of Parthasarathy temple tank, Chennai, India. International journal of Current Microbiology and Applied Sciences 4(4): 168-173.
20. Sweetman E(2009). Microalgae: its applications and potential. International Aqua Feed. Perendale Publishers Ltd. UK.
21. Trainor FR(1992). Cyclomorphosis in *Scenedesmus armatus* (Chlorophyta): an ordered sequence of ecomorph development. Journal of Phycology 28: 553-558.
22. Terry PA, Stone W(2002). Biosorption of cadmium and copper contaminated water by *Scenedesmus abundans*. Chemosphere 47(3):249-255.
23. Wu C, Wang W, Yue L, Yang Z, Fu Q, Ye Q(2013) Enhancement effect of ethanol on lipid and fatty acid accumulation and composition of *Scenedesmus sp*. Bioresour. Technol., 140: 120-125.
24. Zhang J, Volker A. R. Huss, Xuepiao Sun, Kaijun Chang & Daobiao Pang (2008) Morphology and phylogenetic position of a trebouxiophycean green alga (Chlorophyta) growing on the rubber tree, Hevea brasiliensis , with the description of a new genus and species, European Journal of Phycology, 43:2, 185-193.
25. Zou S, Fei C, Wang C, Gao Z, Bao Y, He M, *et al*., (2016). How DNA barcoding can be more effective in microalgae identification: a case of cryptic diversity revelation in Scenedesmus (Chlorophyceae). Sci Rep. 6:36822.